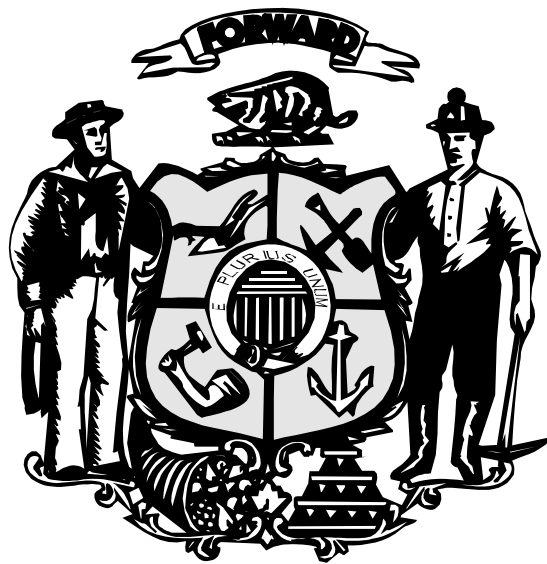


# **MINIMUM REQUIREMENTS AND GUIDELINES FOR FENESTRATION IN THE EXTERIOR BUILDING ENVELOPE**

**State of Wisconsin  
Department of Administration  
Division of Facilities Development**



**Revised 04/20/2015**

# **MINIMUM REQUIREMENTS AND GUIDELINES FOR FENESTRATION IN THE EXTERIOR BUILDING ENVELOPE**

## **INTRODUCTION**

The minimum requirements are to be complied with, as applicable, on all Wisconsin state-owned building projects.

The intent of these minimum requirements and guidelines is to obtain an exterior building envelope that is structurally sound, watertight, cost effective, energy efficient and maintainable. State-owned buildings are typically planned for a life expectancy greater than that proposed/anticipated in the private sector. These minimum requirements are not all-encompassing, but they represent design, materials, techniques and workmanship that have proven successful on building construction in the region of the Upper Great Lakes.

The design and construction of the exterior building envelope should avoid systems and components that have not had a minimum five year history of successful use.

These directions are not intended to stifle creativity or innovations. Architects and Engineers are encouraged to submit a written request for a waiver of specific minimum requirements or time-in-use limitations, along with justification, to the Division of Facilities Development where circumstances warrant such action. A written response with appropriate decision will be provided through the appropriate exterior envelope team member.

Updates to this document and other standards and guides may be found at the Division of Facilities Development [Master Specifications / Design Guidelines](http://doa.wi.gov/Divisions/Facilities-Development/Document-Library) webpage, located at <http://doa.wi.gov/Divisions/Facilities-Development/Document-Library>. If there are questions on any portion of this document or a need to discuss its importance/relevancy, contact Owen Landsverk, Engineering Specialist Management, by telephone: 608/266-1438, Cell 608/575-6439; or via e-mail: [owen.landsverk@wisconsin.gov](mailto:owen.landsverk@wisconsin.gov).

Previous revisions:

- August 9, 2000 (issued 10/1/2012)
- November ,1997
- Guarantee Form (R10/96)

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**MINIMUM REQUIREMENTS  
FOR FENESTRATION IN EXTERIOR WALLS  
ON MAJOR PROJECTS INVOLVING NEW BUILDINGS**

**A. DESIGN**

**1. General Design to be Provided**

- a. Performance criteria established and detailed
- b. Fenestration systems selected appropriate for application
- c. Rainscreen principle through pressure-equalized design
- d. Manufacturer/Fabricator and Installer each an established firm
- e. Fenestration to comply with AAMA/NWWDA 101/1.S.2 HC or AW rating as minimum requirements where applicable
- f. Fenestration system manufacturer's standard or modified-standard product with proven track record
- g. Testing required for units and installation
- h. Thermal barriers within elements
- i. Capability for future maintenance or replacement
- j. Windows accessible for cleaning
- k. Fixed units where allowed by codes
- l. Guarantees for system required
- m. Appropriate fabrication techniques outlined

**2. Design Details to be Provided When Applicable**

- a. Wall cavity openings permanently closed off before window installation
- b. Provision for differential movement between building and fenestration
- c. Interior seal for air/vapor transmission
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- l. Throughwall flashing with drips provided at heads and sills
- m. Relationship of sills to interior air space
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- o. Glass installation to facilitate glass replacement
- p. Appropriate glazing methods
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- r. Hardware options with respect to entrance doors
- s. Hardware requirements with respect to operating vents
- t. Miscellaneous items

**3. Design Details to be Avoided**

- a. Exterior sill projecting into the interior air space or bridging the thermal barrier of the wall systems
- b. Single lines of sealants/caulking as the sole means of preventing water penetration
- c. Noncontinuous thermal break systems
- d. Throughwall flashing exposed inside
- e. Exterior exposed splice covers/sleeves



- f. Concealed overhead door closers
- g. One-quarter inch glazing
- h. Four-sided field structural glazing
- i. Blind seals

## B. MATERIALS

- 1. Frames/elements
- 2. Sealants and caulking
- 3. Flashing and sheet metal
- 4. Glass and glazing
- 5. Finishes
- 6. Hardware

## C. INSTALLATION

- 1. Installation Practices to be Provided When Applicable
  - a. Roles of fenestration manufacturer and approved installer defined
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  - e. Maintenance manual
- 2. Installation Practices to be Avoided
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  - b. Anchorage by other than fenestration installer
  - c. Use of fiberglass insulation as air barrier or vapor retarder

## GUIDELINES FOR AVOIDING CONDENSATION ON FENESTRATION

Condensation Resistance Factor (CRF): A numerical rating system obtained under specific test conditions to show a relative comparison of the condensation performance of fenestration products. A product's ability to resist condensation is greater with a higher CRF number and subsequently a lower U-value. The formula for calculating the CRF is as follows:

$$\text{CRF} = \frac{\text{avg. surface temperature} - \text{outside air temperature}}{\text{inside air temperature} - \text{outside air temperature}} \times 100$$

The CRF rating system was developed to uniformly compare the thermal performance of fenestration under controlled test conditions. CRF is only marginally useful, however, in predicting in-place performance. For sensible value engineering, individual components should have the same CRF value. Averaging a high-performing glass unit and a low-performing frame is not recommended.

Condensation formation depends upon the following variables:

- The ambient interior air temperature.
- The relative humidity (RH) of the interior air.
- The temperature of the surface exposed to the warm, humid air (to a lesser extent, air movement over the interior surface can affect the formation of condensation).

When moisture-laden air hits a colder surface at or below the dew point, the moisture condenses. If the temperature at which air becomes saturated is above the freezing point, the vapor will condense as liquid water. If it is below freezing, it will condense as ice in the form of hoar frost. Condensed water that enters an exterior wall system during cold weather can be far more dangerous than wind driven rain that enters during moderate weather.

Higher interior air temperatures and elevated RH, combined with cold exterior temperatures provide the severest design conditions for condensation control in fenestration. The dew point can be determined from a Psychometric Chart. From this, the surface temperature at which condensation will appear for any given air temperature and RH can be determined.

Typically, a separate CRF is listed for the frame and glass components. Since the CRF uses the average of the interior temperatures measured on the inside surface of a test specimen, it is possible to have a small amount of condensation even though the CRF may exceed AAMA recommendations. The average of the interior surface temperatures may include some local “cold spots” that fall below the dew point. Typically, the sill area is the coldest area in the frame.

ASHRAE 97.5% Dry-bulb Winter Exterior Design Temperature typically used in conjunction with 15 mph winds is based on historical weather data. Extremely cold temperatures can occur during any cold season exceeding the historical weather data. This will affect the product's ability to resist condensation during these extreme conditions, since the inside surface temperatures are directly affected by the outside, ambient air. For additional information refer to the following publications:

- AAMA's [Aluminum Curtain Wall Design Guide Manual](#).

- AAMA 1503.1 Voluntary Test Method for Thermal Transmittance and Condensation Resistance of Windows, Doors and Glazed Wall Sections.
- ASHRAE Handbook - Fundamentals.
- AAMA WSG.1 Window Selection Guide

Fenestration should typically be designed for a minimum interior RH of at least 20 percent during the coldest winter weather.

## **GUIDELINES**

### **FOR IDENTIFICATION AND SELECTION OF THERMAL BREAKS IN FENESTRATION ELEMENTS**

For discussion purposes, “thermally broken” does not contain thermal bridges (less than 1/4” metal separation) as opposed to thermally improved” which does contain some “bridging”. Thermally broken elements are mandated by this document for typical fenestration utilizing metal components.

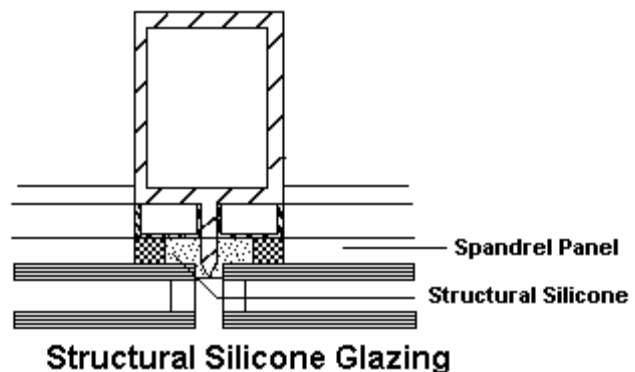
The basic types of thermal breaks include:

- Structural or Stopless Glazing (structural silicone glazing)
- Poured-in-Place Polyurethane and Debridged Metal (poured and debridged polyurethane, P&DB)
- Screw-on-Face with Snap-on Cover (thermal isolators)
- Internal Slide-in Spacer (extruded plastic)
- Structural Gaskets (neoprene zipper)

Each of these designs has viable and appropriate applications. The fenestration manufacturer can recommend the use which is most appropriate to system design parameters. It is impossible to "endorse" only one thermal barrier system, as they all have their own ideal niche, design criteria and quality control requirements. New types or modifications to existing types of thermal breaks are likely in the future.

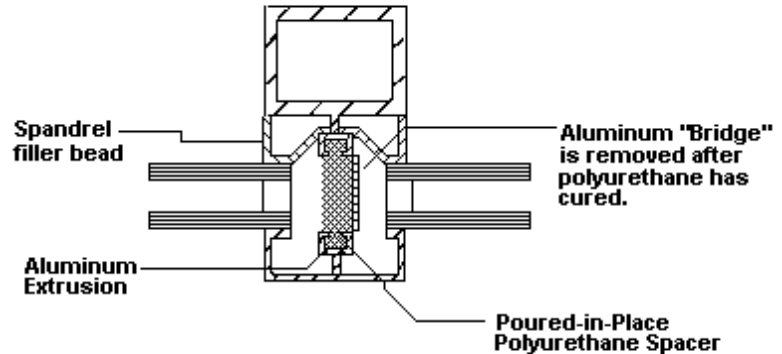
#### **Structural Silicone Glazing**

Structural or stopless systems are considered the best design for thermal performance since there are no exposed mullion surfaces. As shown in the sketch, both the vision and spandrel glass are fixed to the metal support system with structural silicone adhesive sealant. The design of such a system must insure that there are no exposed metal surfaces that will provide a thermal conduction path from the exterior to the interior. To prevent condensation in spandrel areas using monolithic glazing, a vapor retarder is required on the interior of the insulation and framing system to prevent condensation in the cavity behind the spandrel glass. For this vapor retarder to be effective, it must also control air leakage from the building interior into the space behind the spandrel panel. The application of the structural silicone requires great care with regard to cleanliness, temperature conditions and curing without stress on the silicone. These requirements lend this system to the factory assembly of large panels and on-site erection. ASTM STP 1054 contains several articles on structural silicone glazing systems, though not from the perspective of thermal performance. These articles cover design considerations, performance properties of the adhesives, methods for calculating joint dimensions and other issues.



## Poured-In-Place Polyurethane and Debridged Metal

Poured-in-place polyurethane mullion systems have been widely used in less expensive curtain wall systems, for a long time. As shown in the sketch, the system is based on a poured-in-place spacer which serves as a thermal break, as well as a structural element. A receiver pocket is extruded into the framing system, which later receives a hot molten polyurethane. After the polyurethane hardens, a portion of the metal pocket is machined out to

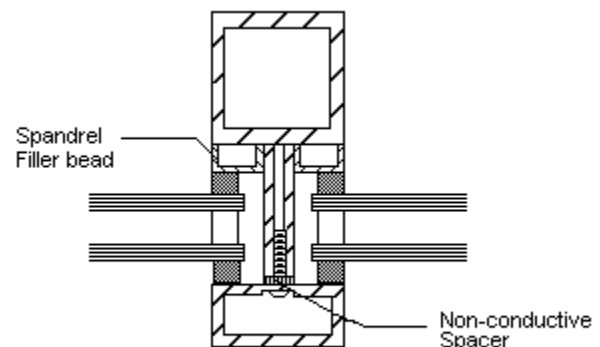


**Poured in Place Mullion**

eliminate the metal-to-metal connection between inside and out. Due to structural considerations, this system is not recommended for use in "high performance" curtain walls where severe wind loads are expected. The polyurethane spacer must transfer all loads applied to the exterior face into the structural framing. These materials can become brittle in very cold temperatures and soften in very hot temperatures. Thus, material selection is a very important issue. The framing must be designed so that the polyurethane filler forms a continuous thermal break. Sometimes spandrel filler beads bridge the thermal break and such designs should be avoided. Another issue with this system is that many A/E's prefer only about 2 1/2 inches of exposed framing, and that is not enough to achieve adequate structural performance. Three and one-quarter inches is a preferable minimum dimension. Skip de-bridging and/or use of metal fire clips change the system from thermally broken to thermally enhanced, which is not allowed.

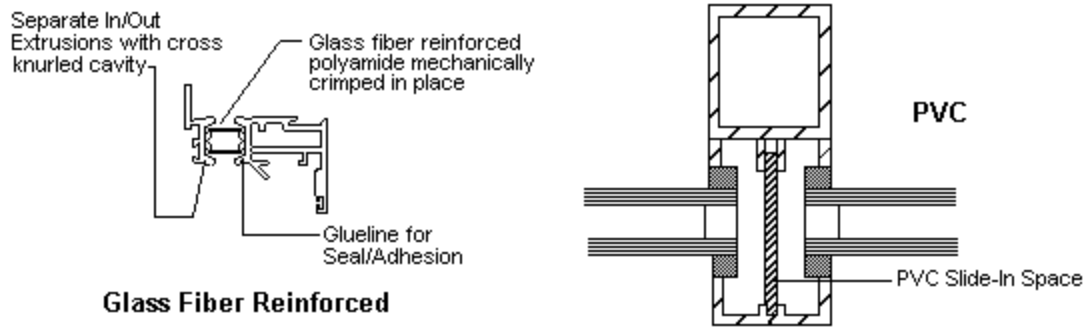
## Screw-On-Face with Snap-On Cover

This is a fairly standard system offered by most curtain wall manufacturers. As shown in the sketch, the thermal break is provided by a low-conductivity spacer, usually made of vinyl or rigid, polyvinyl chloride (PVC). The design of the spacer is critical in terms of material selection and its long term ability to seal out water. The exterior extrusions are attached with screws, whose size, type and spacing are based on structural considerations. In designing these systems, the potential bridging caused by spandrel glass adapters must also be reviewed.



**Screw-On Face Mullion**

## Internal Slide-In Spacer



### Slide-In Spacer Mullions

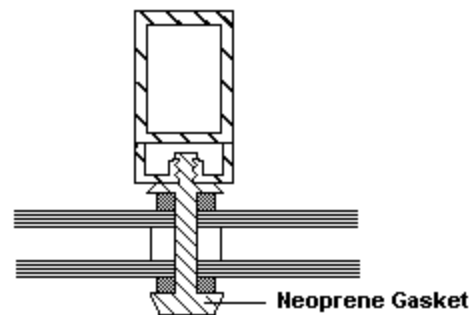
The sketches show schematics of this system in which the interior and exterior metal is separated by a slide-in separator. These spacers are designed to transfer the structural loads to the interior framing and are installed in the framing at the fabrication shop. The structural properties of the plastic material are key to this system.

Glass fiber reinforced polyamide thermal barrier systems were pioneered in Europe in the early 1980's. After the separator strips are installed, they are mechanically crimped-in-place. This method has high temperature structural performance and long-term dimensional stability, making it a good alternative to P&DB. The system lends itself to a two-color option with minimal added expense.

Extruded, slide-in PVC thermal barrier systems are commonly used in commercial curtain walls.

## Structural Neoprene Gaskets

In structural, or zipper gaskets, an extruded neoprene gasket that incorporates glazing pockets is attached to a metal support system. This system, shown in the sketch, is simple, and the thermal performance is generally excellent. Visual appearance, the structural support system, the size of the gaskets and the anticipated building movements must be considered in specifying this type of system. It is usually used in small to medium scale buildings of limited height to create strip systems or vertical ribbon systems. Maintenance of this system is critical as the neoprene is exposed to the elements; concerns have been expressed about the life expectancy of the neoprene.



### Structural Neoprene Gasketed Mullion

**THERMAL BARRIERS TABLE 1**  
(Comparative Advantages)

<b>POLYURETHANE POURED-AND-DE-BRIDGED</b>	<b>GLASS FIBER REINFORCED BARRIER</b>	<b>PVC SEPARATORS</b>
Low Cost	Remains Strong at High Temperatures	Structural Integrity not Dependent on Elastomers
Close Tolerances on Section Depth Dimension due to Single Extrusion	Long-Term Dimensional Stability (No Dry Shrinkage)	Long-Term Dimensional Stability (No Dry Shrinkage)
Design Flexibility	Large Composite Sections Possible	Large Composite Sections Possible
Simple One-Piece Design	Two-Color Option Available	Two-Color Option without Expensive Masking
High Strength at Normal Temperatures	Mechanical Interlock can be Tested On-Line	Can be Refinished
Widespread Availability	Can be Refinished	Design Flexibility
Easy to Seal Initially at Corner joints	Not Dependent on Chemical Bond for Performance	Not Dependent on Chemical Bond for Performance
	Long History of Successful Performance in Europe	Can be Rolled in any Direction

**THERMAL BARRIERS TABLE 2**  
**(Comparative Disadvantages)**

<b>POLYURETHANE POURED-AND-DE-BRIDGED</b>	<b>GLASS FIBER REINFORCED BARRIER</b>	<b>PVC SEPARATORS</b>
Relatively Low Heat Deflection Temperature	Relatively Complex 4-Piece Design	Relatively Complex Multiple-Component Design
Limited Cross Sectional Size due to Single Extrusion	Design Flexibility Limited by Access Required for Knurling and Crimping	Many Pieces to Assemble in the Shop or Field (High Cost)
Cannot be Rolled after Application	Limited Domestic Availability	Corner Joinery Sealing is Made Difficult
Risk of Long-Term Dry Shrinkage	High Material Cost	Vapor Barrier Continuity is Difficult, if Separators are used at the Interior
Low Impact Strength	Line Set-up Profile Changes is Time-Consuming	Questionable Tolerances on Section Depth Dimension due to Multiple Components
Wet Distortion in Large Sections	High Scrap Cost	
Surface Treatment Affects Performance	High Labor Cost	
Cannot be Refinished	Corner Joinery Sealing is Made Difficult	
Two-Color Finish Requires Expensive Masking		
Cannot Test for Adhesion On-Line		

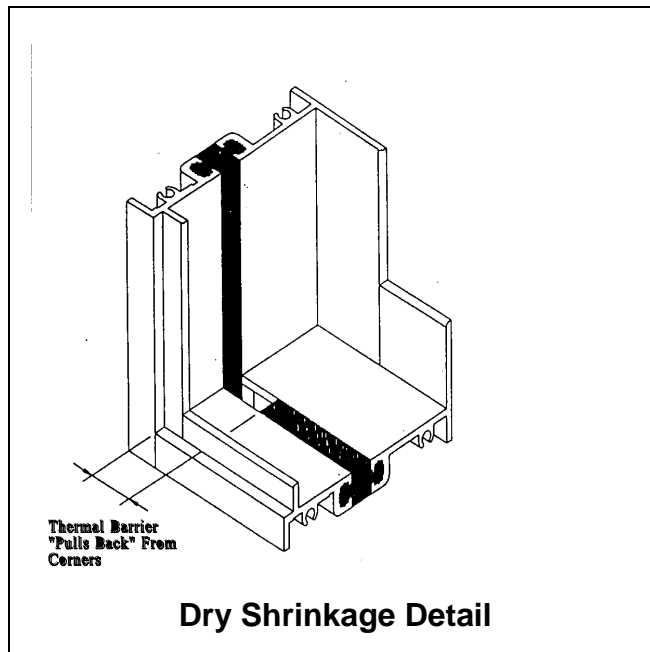


# **GUIDELINES FOR MINIMIZING DRY SHRINKAGE WHEN USING POLYURETHANE POURED AND DEBRIDGED THERMAL BARRIERS**

"Dry shrinkage" of poured-in-place polyurethane thermal barriers is evidenced by a long-term "pull back" of barrier ends on extrusions of various lengths. This results from a loss of adhesion between the cured resin and the walls of the extruded cavity into which it was poured. It is usually noticed at the sill of glazing cavities or operating window frame joints. In severe cases, this shrinkage can cause frame joinery sealant to separate, with subsequent leakage into the wall cavity.

The causes and mechanisms of dry shrinkage are complex. Many variables can affect the long term dimensional stability of thermal barrier sections, including cavity size, extrusion design, material properties, surface treatment and cavity contamination.

In 1991, AAMA conducted a survey of 137 manufacturers requesting information on their companies' experiences with dry shrinkage. Fewer than 40 projects were identified as problematic. In the past ten years, many of the companies that were involved with such problems have subsequently gone out of business or been substantially reorganized. Thousands of successful projects are now completed each year with the incidence of excessive dry shrinkage becoming a more uncommon phenomenon.



Tests for tension, torsion and shear strength, developed in the mid-1970's, have evolved into accepted industry criteria for structural evaluation of thermal barrier composites.

In 1981, AAMA organized the Thermal Break Structural Task Group, with the involvement of engineers and chemists from many manufacturers and thermal barrier resin suppliers. This group prepared a Technical Information Report (TIR) for the industry establishing performance standards, processing recommendations and uniform structural test methods for thermal barriers. It was published in late 1990 as AAMA TIR-A8.

The work of this AAMA task group has continued, resulting in the survey previously cited, a field repair method (AAMA Technical Bulletin 91-01), a draft dry shrinkage test method, and a quality assurance processing guide for thermal barrier applicators. The task group also meets regularly with specifiers and code officials to keep them abreast of ongoing activities.

Quality conscious manufacturers recertify thermal barrier design and processing through a rigorous series of laboratory tests including:

- Tensile strength tests.
- Torsional strength tests.
- Shear strength tests.
- Impact strength tests.
- Thermal cycling.
- Guarded hot box thermal performance tests.

Production line testing and quality control procedures include:

- Daily non-destructive testing of production materials with both organic and anodic surface treatments.
- Daily sample coupon testing on finishing production runs.
- Daily in-line verification of mix ratio, uniformity and gel time.
- Frequent wet distortion measurements.
- "Real time" environmental monitoring.

A 10-year warranty is available from some manufacturers that includes the poured and debridged polyurethane thermal barrier (P&DB).

There is no danger of separation of exterior portions of thermal barrier sections from interior portions, even if limited dry shrinkage has occurred. Other more serious material problems would need to be present, which would be obvious upon inspection (e.g., change of color, fracture, crazing, etc.). Dry shrinkage alone is not cause for alarm.

A small amount of dry shrinkage at the ends of cut lengths indicates a loss of adhesion at those points. Dry shrinkage is a concern because of the potential for water penetration into the wall beneath the window if functioning flashing is not provided.

Major thermal barrier material supplier laboratories have developed new low-shrinkage resin compounds, surface primers, and mechanical interlocks, such as crimping, to minimize the potential for dry shrinkage.

Thermal barrier structural testing criteria, as included in AAMA TIR-A8 should be specified. This helps ensure that tensile, torsional and shear strengths meet appropriate design criteria.

The following requirements should be incorporated into bidding documents when poured and de-bridged polyurethane material is used:

Polyurethane thermal barriers shall be tested as per AAMA TIR A8-90 and AAMA Draft #13 of AAMA's Dry Shrinkage & Composite Performance Thermal Cycling Procedure for validation testing at differential temperatures. At the conclusion of the tests, the shrinkage shall be equal to or less than the prescribed 0.10%.

Use of poured and de-bridged polyurethane thermal beak assemblies will require window manufacturer's prior adoption and continued use of the procedures and quality control features

outlined in AAMA's Quality Assurance processing guide For Poured And De-bridged Polyurethane Thermal Barriers.

**(GLAZING SYSTEM) / WINDOW GUARANTEE**

***SEE FORM IN SEPARATE DOCUMENT***

# **COMMENTARY ON MINIMUM REQUIREMENTS FOR FENESTRATION IN EXTERIOR WALLS ON MAJOR PROJECTS INVOLVING NEW BUILDINGS**

## **INTRODUCTION**

This commentary provides information to allow a more knowledgeable decision in the selection of design, material, construction methods and craftsmanship for the exterior building envelope of major state projects involving new buildings or major additions thereto.

Included is background data used in the development of the Minimum Requirements and Guides, Pages I. 1-2, along with insight on why the involved items were adopted. It is an outgrowth of the knowledge and experience gained by field review of exterior building envelopes. The underlying premise is to highlight those things based primarily on performance longevity that either work well or work poorly. This commentary on the minimum requirements and guides is intended to portray the leading-edge-of-technology (former state-of-the-art) knowledge. Graphic details, guide specifications and other examples are also provided to supplement this commentary.

All the information contained in both standards and guides, as well as in the commentary, will be periodically reviewed and updated as additional facts that warrant changes become available.

## **DEFINITIONS**

**Clerestory:** An exterior building assembly rising above adjacent rooftops and having vertical glass windows admitting daylight to the interior with a roof assembly.

**Curtainwall:** An exterior building wall framework assembly carrying no roof or floor loads, consisting of metal, glass, and other surfacing materials, and extending beyond the outside edges of the floor slabs. The curtainwall can represent the entire skin of a building or a portion of the exterior facade. In either case, curtainwall is used above ground level in multi-story applications.

**Entrance doors:** Entrance doors most commonly incorporated into the storefront assembly consist of stile-and-rail type swing doors but may also include flush doors, revolving doors, balanced doors, sliding doors, and automatic entrance doors.

**Fenestration:** When the word "fenestration" is used in this document, it collectively means storefront, window, window wall, and curtainwall.

**Skylight:** An exterior building assembly rising above adjacent rooftops and having sloped glass windows admitting daylight to the interior without having a roof assembly.

**Storefront:** An exterior building wall assembly of framing, fixed glass and other surfacing materials which forms a continuous glazed area carrying no roof or floor loads and typically located at the ground level and limited to a single vertical span. Storefront framing often incorporates entrance doors and frames.

Window: An opening in an exterior wall of a building to admit light and/or air, which may contain fixed window units or equipped with sashes that enclose one or more panes of glass and can be capable of being opened and closed. The head, jamb and sill members each abut the building construction. Generally the window wall is comprised of numerous windows designed to mate (stack) with one another either horizontally or vertically. Horizontal and vertical multiples are referred to as "ribbon windows" or "strip windows."

Window Wall: An exterior building wall framework assembly carrying no roof or floor loads, consisting of metal, glass, and other surfacing materials, and extending between the outside edges of the floor slabs. The system typically consists of vertical and horizontal framing members, containing fixed lights or opaque panels or any combination thereof. The window wall can represent the entire skin of a building or a portion of the exterior facade. In either case, window wall is used above ground level in multi-story applications.

### **SPECIFIC REFERENCE**

Envelope Design Guidelines for Federal Office Buildings: Thermal Integrity and Airtightness, National Institute of Standards and Technology, March 1993.

### **GENERAL REFERENCES (latest edition)**

AMERICAN ARCHITECTURAL MANUFACTURERS ASSOCIATION (AAMA)

Aluminum Storefront and Entrance Manual.

Structural Sealant Glazing Systems (A Design Guide) Aluminum CW Series No. 13.

AAMA 501.2 Field Check of Metal Curtain Walls for Water Leakage.

AAMA 501.3 Field Check of Water Penetration Through Installed Exterior Windows, Curtain Walls and Doors by Uniform Air Pressure Difference.

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AAMA 502 Voluntary Specification for Field Testing of Windows and Sliding Glass Doors.

AAMA 503 Voluntary Specification for Field Testing of Metal Storefronts, Curtain Walls and Sloped Glazing Systems.

AAMA TIR-A8 Structural Performance of Poured and De-bridged Framing Systems. Technical Bulletin 91-01, Field Repair Method.

AAMA WSG.1 Window Selection Guide.

AAMA/NWWDA 101/1.S.2 Voluntary Specifications for Aluminum, Vinyl (PVC), Wood Windows and Glass Doors.

NATIONAL WOOD WINDOW & DOOR ASSOCIATION

AMERICANS WITH DISABILITIES ACT - ACCESSIBILITY GUIDELINES (ADA-AG)

BUILDERS HARDWARE MANUFACTURERS ASSOCIATION (BHMA)

DOOR AND HARDWARE INSTITUTE (DHI)

THE NATIONAL ASSOCIATION OF ARCHITECTURAL METAL MANUFACTURERS  
NAAMM Metal Finishes Manual

## A. DESIGN

It is desirable that each element of the exterior envelope be developed by an expert in the specialty area involved. In reality, such a goal is seldom achieved. With fenestration, it is quite common for the A/E to utilize the expertise readily available through most of the major manufacturers in order to develop the basic design intended. Standard details of a specific manufacturer are thus, sometimes used as the basis for generically portraying the design intent. It is extremely important, however, that the details used are not proprietary nor inhibit reasonable competition. In most cases this can be practically achieved in a number of ways.

Fenestration design information and details in this document are generic and do not address complex configurations. Details to be considered include intersections of horizontal and vertical mullions, doglegs and other transitions. The lack of adequate design details for these complexities is a common source of performance problems due to the unusual stresses and movements that occur at these locations. An adequate design must include details for all mullions, intersections between mullions and locations where curtain walls meet other envelope systems. Without the provision of design details for all locations, the installation at these irregularities is left to the mechanic in the field.

### 1. General Design to be Provided

**a. Performance criteria established and detailed:** See table of Window Performance Requirements on following page, as a sample. Type of thermal barrier and its location should be included.

**b. Fenestration systems selected appropriate for application:** Each of numerous fenestration designs has viable and appropriate applications. The fenestration manufacturer can recommend the use most appropriate to system design parameters. It is difficult to use only one fenestration system universally, as they all have their own ideal niche.

Architects/Engineers should meet with fenestration and glass manufacturer representatives, in advance of construction document preparation (drawings and specifications) to discuss fenestration performance, glass, sealants, and hardware, in order to select products appropriate for the application.

**c. Rain screen principle through pressure-equalized design:** Water leakage will occur in the presence of three things: water, an opening, and a force to pull the water through the opening. Rain screen principle assumes the first two things will exist and therefore concentrates on minimizing or eliminating the force. This is accomplished by having the following:

An exterior rain barrier to impede water penetration and having protected openings leading to the exterior. Pressure differential across the joints of the rain barrier is minimized or eliminated.

An air space behind the rain barrier in which the air pressure is virtually equal to the air pressure on the exterior face of the rain barrier. The air space should be divided into relatively small compartments, each having openings to the exterior.



## WINDOW PERFORMANCE REQUIREMENTS

Item	Limitations	Test Method
Structural Adequacy	Unit to be tested at 1.5 times design wind pressure, both positive and negative, acting normal to plane of wall; with no glass breakage; no permanent damage to fasteners or hardware parts, or damage to make window inoperable or permanent deformation of any main frame or ventilation section in excess of 0.2 percent of its span, or deflection of any unsupported span (meeting rails, muntins, frames, mullions, or other appurtenances) in excess of L/175.	ASTM E330
Water Penetration Resistance	No uncontrolled water leakage at specified performance level.	ASTM E331
Air Infiltration Resistance		
Operable Units	Maximum air infiltration of 0.10 cfm/square ft. of window.	ASTM E283
Fixed Units	Maximum air infiltration of 0.06 cfm/square ft. of window.	ASTM E283
Thermal Transmission Resistance	Maximum "U" factor, in accordance with ILHR 63.	AAMA 1503.1
Condensation Resistance	Condensation Resistance Factor (CRF) to be minimum 56/frame and 50/glass, with 30 percent inside relative humidity, and 68 degree F temperature.*	AAMA 1503.1
Sound Transmission Resistance	Sound Transmission Class (STC) for typical applications to be minimum of 32	ASTM E413

\*(See "Guidelines for Avoiding Condensation on Fenestration," Page II.1)

A structural barrier at the interior side of the air space relatively impervious to air and vapor. Primary seals occur in this barrier and are relatively protected from the elements thereby increasing the sealants' durability and longevity. The continuity and structural integrity of the barrier must be maintained.

In fenestration design, it has been proven that weatherseals are considerably more effective by providing a gap between the lower lip of the ventilator frame flange and the fenestration frame sill, instead of creating a tight seal along this edge.

In curtainwall design, pressure in the air cavity at all exterior openings, must be as high as the air pressure on the exterior face of the rain barrier. Otherwise, water will be drawn into the cavity. Wind pressures on large and/or tall facades are more variable, and positive pressures increase with height.

As a rule of thumb, the minimum ratio of the total area of openings, to the exterior, to the aggregate area of all openings connecting the pressure-equalization chamber, to the building interior, should be 10:1.

**d. Manufacturer/Fabricator and Installer--each an established firm:**

**Manufacturer/Fabricator Qualifications:** Fenestration systems should be fabricated by a firm experienced in producing systems similar to those indicated for the project being bid, and whose work has resulted in a record of successful in-service performance during the immediate past three to five years. The fabricator should have sufficient production capacity to produce required components without causing delays in the work.

**Installer Qualifications:** An experienced installer, having completed installations of fenestration similar in design and extent to those required for the project being bid and whose work has resulted in construction with a record of successful in-service performance during the immediate past three to five years.

**e. Fenestration to comply with AAMA/NWWDA 101/1.S.2 HC or AW rating, as minimum requirements where applicable:** The recognized standard for performance ratings of windows is AAMA/NWWDA 101/1.S.2.

Five performance grade designations denote the product's intended application: "R" for residential, "LC" for light commercial, "C" for commercial, "HC" for heavy commercial, and "AW" for architectural.

HC units are the minimum performance level specified on projects that fall within product size and performance limitations. AW windows are of a grade and class generally used in commercial and monumental type buildings, such as schools, hospitals, institutions or libraries, that require durability and overall higher performance standards. This grade typically has higher structural and thermal performance, longer life expectancy, consistency of construction stability and performance, in addition to minimum maintenance required for retaining aesthetic appearance.

The minimum classification for both HC and AW products is a design level of "40" (HC 40 / AW 40). Levels above 60 are advertised and available, however at the "60" level, the structural test pressure is  $\pm 90$  psf, which relates to a 190 mph wind speed.

The classification and grade levels are determined by laboratory testing of specific window sizes and configurations for air, water, and structural performance and are intended as a comparison method

between products. The actual structural performance requirement of an installed product configuration must meet the governing codes of the project.

**f. Fenestration system manufacturer's standard or modified-standard product with proven track record:** Manufacturers' existing products or an existing product line with minor modifications/alterations to meet job-specific installation conditions should be used. These systems have been tested in the laboratory and display a record of installed performance.

Job-specific custom window systems can be developed to meet aesthetic or configuration requirements, however using a custom application may result in higher initial product costs and construction delays in verifying the performance of the system. If a custom system is used, laboratory testing and installation performance mockups are mandatory prior to final approval.

**g. Testing required for units and installation:** See "Field Testing" under "Installation Practices to be Provided When Applicable" for general requirements.

**h. Thermal barriers within elements:** Thermally-broken elements are required for the exterior facade of all facilities that are heated or cooled.

See "Guidelines for Identification and Selection of Thermal Breaks in Fenestration Elements" for related information.

**i. Capability for future maintenance or replacement:** Design consideration should be given to the fact that fenestration systems are a maintenance item, during the overall life of a building.

Primary maintenance normally encountered involves glass replacement. Under normal conditions, fenestration systems that have the vision glass replaceable from the interior should be used; however, some projects may require window or wall systems that require glass replacement from the exterior due to security, and/or spandrel glass or large glass lites that cannot be physically moved within the building to the replacement site.

The next level to consider is possible replacement requirements for hardware, weather-stripping or blinds due to user abuse or long term use. Quality conscious architectural grade fenestration manufacturers use high quality materials that withstand normal usage. Systems are designed that permit easy field replacement of these items. The major consideration to be addressed in the specifications is providing some means for on-site custodial use of attic stock on highly abusive projects, such as schools and dormitories. Custom-sized items, such as glass and blinds, may or may not be feasible--depending on the number of different sizes and site storage available. Standard hardware subject to abuse, such as cams, roto's or 4-bars, may be stocked for replacement. In all cases, the specifications should require that final record drawings, warranties and spare parts lists be furnished to the Owner's Project Representative.

Fenestration replacement is not normally expected due the long-term durability of systems used. However, certain building types and applications, such as hospitals, may require individual unit replacement because of changing room use. The installation details should be reviewed on such projects to permit future changes with receptor systems or exposed anchor/trim systems.

**j. Windows accessible for cleaning:** Glass should be periodically cleaned to maintain its psychological benefit and user-friendly environment. Depending on the project, this may involve weekly cleaning of interior lites in a hospital or perhaps once or twice a year for other projects. Compared to the simple cleaning of interior glass lites and enclosed glass surfaces in dual-glazed units, exterior glass cleaning can range from a relatively simple operation of opening the window and washing it from the room interior, to a very costly procedure using swing-scaffolds or special exterior lifts. Based on building type, height, fenestration configuration, usage, etc., consideration should be given to the design of an appropriate method of cleaning access. A combination of operating units (venting or custodial control) within fixed lite strips allows access to the exterior surface but may substantially add to cost. High-rise buildings or buildings with interior access difficulties may be designed for exterior cleaning using swing-scaffolds. When this procedure is employed, care must be provided to protect the exterior surfaces. Building overhangs, sun screens or similar ornamentation may prevent access. Deeply recessed fixed windows may also create difficulty for cleaning. Fenestration may be washed from the exterior or interior of the building. The Architect/Engineer's selection of fenestration type and placement within the exterior wall plane will determine the appropriate cleaning method and its related maintenance costs.

**k. Fixed units where allowed by codes:** In combination with modern HVAC systems, the recommended fenestration type is fixed-lite glazing. This allows complete control of the interior building environment by the HVAC system and utilization of the least costly fenestration system, while providing the largest uninterrupted vision areas possible.

Prior to using fixed-lite glazing system only, all relative building and occupancy codes must be reviewed to determine if any operating units are required for emergency venting, emergency egress (escape), window washing, etc.

**l. Guarantees for system required:** The General Prime Contractor is to provide a written guarantee warranting all window and related work under Contract to be free from defects in materials and workmanship for extended periods of time as stipulated in the guarantee form. The General Prime Contractor's Performance-Payment Bond is not required to apply to any extended guarantee period beyond the first year, required for all work under Contract. See "Written Guarantee" for specific requirements of the guarantee.

Enforcement during construction of required materials and workmanship is essential to a successful project, rather than relying solely on a guarantee.

**m. Appropriate fabrication techniques outlined:** See "Frames/Elements" under "Materials" for information.

## **2. Design Details to be Provided When Applicable**

**a. Wall cavity openings permanently closed off before window installation:** The cross section of openings in exterior walls to receive windows or doors is to be sealed with closed cell rigid insulation or foam and sealant, as appropriate, prior to window installation. Seal is to prevent inside or outside air from entering the wall cavity or air within the wall cavity from escaping, at the perimeter of the opening. Such efforts are intended to retain the integrity of a rain screen wall, with its required venting of the wall cavity to the outside. Without insulated and air-tight perimeters, the thermal barrier in the fenestration units could be bypassed. Where concrete block backup is used, the transfer of

heat and cold to interior metal wall components can be minimized by insulating a portion of the wall cavity width. Specifications should require the wall cavity closure to be completed before window installation is started. See Fenestration-Opening Juncture Detail on following page.

Jamb, head and sill closures at frame sections to seal off the cavity air and provide supports for the perimeter sealant backer rod should be detailed. A suitable material for closures is PVC (polyvinyl chloride). See Details DT-1, DT-2, DT-4 and DT-5.

**b. Provision for differential movement between building and fenestration:** Joints for movement should be a minimum of 3/8" wide, having high-range movement capability (plus or minus 50 percent). Joints should be appropriately designed, so their width can sufficiently accommodate anticipated movement (tensile, shear, etc.) relative to the performance capabilities of the sealants specified. The coefficient of thermal expansion for aluminum is  $12.9 \times 10^{-6}$  inches/inch/degree F, which is far greater than other common building materials utilized in construction.

**c. Interior seal for air/vapor transmission:** The primary seal of most standard curtainwall systems is placed behind the interior plane of the glass and requires backup for sealant in the wall cavity.

AAMA 502 and AAMA 503 specify field test procedures for measuring air infiltration and water penetration. See the "Field Testing" article herein for more information.

**d. Thermal barriers and location:** Select type and indicate position in the completed elements.

See "Guidelines for Identification and Selection of Thermal Breaks in Fenestration Elements" for related information.

**e. Anchorage materials and methods:** Anchor bolts used at curtainwall anchors should be double-nutted, or threads should be stripped to prevent loosening. Loctite, Ny-Lok, Whiz Nut, etc., are preferred over upsetting the threads (e.g., "reversible").

The fenestration manufacturer should provide the proper clips or anchors necessary for perimeter attachment, which adequately transfer loads to the structural supports. See Details DT-1, DT-2, DT-4 and DT-5.

**f. Isolation of parapets and roofing from the fenestration system:** Parapets and roofing materials should be isolated from curtainwall components to permit independent movement of each.

**g. Structural calculations submitted by manufacturer:** Structural calculations prepared by the fenestration system manufacturer should indicate wind load on horizontal and vertical mullions, dead and live loads and shear, torsion, and tension loads on structural members and anchorage. Stamping and sealing structural calculations depends on the project's extent and complexity.

**h. Water collection from surrounding construction and weepage to exterior:** Weepage is evaluated on an individual-lite basis. Slotted holes are more effective than round holes in evacuating penetrated water. Also provide for condensation weepage.

**i. Head channels and sill starters:** Head and sill starters should be used in ribbon (strip) window applications. Starters facilitate leveling of the opening and accommodate live load floor deflection and thermal expansion. Head starters are usually unnecessary for punched windows, unless they are factory-glazed with no way to hide the anchors. See Details DT-1, DT-3, DT-4 and DT-6.

For fenestration openings 20'-0" wide or greater, a sill starter with an integral, water reservoir is required since water may penetrate the vertical stack joints of the fenestration system over time. This type of sill starter should permit collection and drainage of same. Ends of starters should be end-dammed, sealed to masonry jambs, and tied into perimeter sealant line.

Splice-joints for head and sill starters and brake metal should allow 1/2" for thermal expansion/contraction and utilize a band-aid or hourglass joint seal unless otherwise dictated by lengths involved. The back-up splice should utilize bond breaker tape to eliminate three-sided sealant adhesion. Exterior exposed splices are not recommended. Splice plates, bond breakers, extruded silicone strips, and similar devices may be used in several variations in conjunction with low-to-medium modulus sealant.

**j. Head, jamb and sill details:** Thorough detailing head, jamb, and sill conditions showing juncture between horizontal and vertical members is critical to minimizing air infiltration.

**k. Isolation of interior wall and ceiling material from the fenestration system:** Interior wall and ceiling materials should be isolated from the fenestration system to accommodate design movement of the system and eliminate drywall problems. For example, curtainwall systems can have an integral drywall trim pocket member at sill. See Details DT-1, DT-2, DT-4 and DT-5.

**l. Throughwall flashings with drips provided at heads and sills:** End dams should be provided at the longitudinal ends of flashings. The "horizontal" portion of the metal flashing should tip down going out. The flashing should extend out beyond the face of the exterior wall and then be cut and hemmed neatly with a minimum 3/4" extension bent downward 45 degrees to serve as a drip. Drips help to keep windows cleaner. If the throughwall flashing is back-sloped, this bad condition funnels exterior water into the wall rather than out, and the problem is exaggerated if the flashing projects as a ledge beyond the face of the wall.

**m. Relationship of sills to interior air space:** Exterior aluminum sills should neither project into the interior air space nor bridge the thermal barrier of the wall system. If the design indicates a deep or steeply sloped sill member, the area underneath the sill should be insulated. Use stainless steel or non-metallic sills where frequent contact is made with de-icing salts (e.g., adjacent to sidewalks).

**n. Fenestration to facilitate remedial caulking:** Consider the feasibility of remedial caulking during the selection of fenestration design. Sealants will fail over time, especially if not properly applied and maintained, and will require replacement.

**o. Glass installation to facilitate glass replacement:** Fenestration installation methods should permit easy glass replacement in the field.

**p. Appropriate glazing methods:** When selecting a fenestration system, the design should address whether or not reglazing from the interior is desired or required.

Factory-glazing ensures the highest quality control. However, the glazing method to be used depends on the fenestration system design and the experience of the glazing subcontractor, because he/she is best equipped to control quality and labor costs, based on field-glazing versus shop-glazing.

See "Four-Sided Field Structural Glazing" under "Design Details to be Avoided" for related information.

**q. Weather-stripping to facilitate replacement:** Fenestration installation methods should permit easy replacement of weather-stripping. The fenestration manufacturer and installer should review maintenance and weather-strip replacement procedures with the Owner's Project Representative.

**r. Hardware options with respect to entrance doors:** See "Hardware" under "Materials" for information.

**s. Hardware requirements with respect to operating vents:** When selecting hardware for operating vents, it is important to acknowledge the application of the installed product. The selection of locks, hinges and operation mode will affect the overall function of the operating vent. Architects/Engineers are encouraged to meet with the fenestration manufacturer to ensure that the hardware selection will meet the expectations of the end user of the product. Special consideration must be given to ADA-AG requirements and psychiatric/detention applications. Applicable building codes may also dictate the type of ventilating hardware needed for the type of building being constructed. Smoke evacuation, egress, ingress, access, security, and safety are some examples of other things to consider when selecting hardware. For further information, refer to AAMA WSG.1.

**t. Miscellaneous items:** Non-typical situations also require details.

Thermal storefront framing systems can be provided with a field-installed, snap-cover thermal plate or rigid extruded insulation around fenestration unit perimeter for sealant backer rod. However, this must be specified and detailed. Foam insulation is expensive and causes undue pressure on the fenestration unit. Also, its blind application cannot ensure that voids are being filled.

Provide semi-rigid curtainwall insulation with scrim-reinforced foil facing behind 1" insulating spandrel glass. Mechanically attach insulation board to the curtainwall frame. Allow a 1" minimum air space between the glass and insulation. Provide for condensation weepage.

Incorporate metal wall panels at spandrel conditions, into the curtainwall system, and direct water flow to the exterior.

### 3. Design Details to be Avoided

**a. Exterior sill projecting into the interior air space or bridging the thermal barrier of the wall systems:** See "Relationship of sills to interior space" under "Design Details to be Provided when Applicable" for information.

**b. Single lines of sealants/caulking as the sole means of preventing water penetration:** Sealant materials have a finite life and must eventually be replaced. It is not a question of "if" but rather "when". Location, exposure, joint design, material used, joint preparation and application may result in drastic time differences before joint failure (water penetration) results. When the sealant is required to serve as a skin, then any break is accompanied with the potential for instant water penetration, which is highly undesirable. Options should be considered when developing details for the exterior envelope. Double lines of sealant or screen walls should be used to protect the primary seal from direct exposure to rain and UV degradation. Movement of water by capillary action can readily be controlled by the use of drips, gaps and membranes.

**c. Non-continuous thermal break systems:** Thermal slot systems, which are common to storefront systems, are used to reduce thermal mass and thermal transfer in an effort to improve thermal performance. All framing systems having slotted holes require investigation of thermal integrity and structural integrity/twist of vertical mullions. Sealing the slotted system in the horizontal position may be difficult. Specifying a 56 or higher CRF precludes the use of thermal slot framing. Skip de-bridging and/or use of metal fire clips also change the system from thermally broken to thermally enhanced, which is not allowed.

**d. Throughwall flashing exposed inside:** When thermally unbroken metal flashing is exposed on both inside and outside of the exterior wall system, substantial heat transfer by conduction will occur and condensation can be expected. During extremely cold weather, the temperature of the interior side of metal flashing may be such that the vapor will condense as ice in the form of hoarfrost and the buildup may be appreciable. As rapid melting of this buildup occurs, the extensive water formed may enter the exterior wall system causing damage or may play havoc with interior finishes. Even if the flashing is hidden and terminates on the warm side of the wall, condensation may still occur, unless the flashing is thermally broken.

**e. Exterior exposed splice joints:** See "Head Channels and Sill Starters" under "Design Details to be Provided When Applicable" for information.

**f. Concealed overhead door closers:** Concealed overhead closers do not perform well at low temperatures.

See "Hardware" under "Materials" for other options.

**g. One-quarter inch glazing:** Desired low "U" factors and high "CRF" values preclude the use of such glass in typical applications.

**h. Four-sided field structural glazing:** Four-sided structural glazing involves securing materials to a perimeter support system with a high-grade structural silicone glazing sealant. To retain the glazing infill material, 4-sided systems totally rely on the integrity of the silicone's adhesive/cohesive characteristics and the quality control methods used during its application. Systems



utilizing 4-sided applications must have the initial glazing and reglazing operations performed in the shop, under controlled conditions. Four-sided, structural glazing, framing support systems must be removable and replaceable for reglazing purposes. For further information, refer to AAMA Aluminum Curtainwall Series No. 13.

Limit field structural silicone glazing to two parallel sides, with the other two parallel sides supported within the frame providing mechanical glazing pockets.

i. **Blind seals:** Blind glazing as an example, which is application of sealant without being able to observe placement of the bead, should not be used.

## **B. MATERIALS**

1. **Frames/Elements:** The type of framing construction to be used is directly related to the performance and appearance of the installed product. Typically, window units are prefabricated while curtainwall systems can be assembled and installed in several ways. Curtainwall systems range from finished stock lengths to preglazed unitized modules. The level of quality control will vary with the amount of factory-fabrication and -assembly performed. Alignment of framing members and the application of critical frame seals are typically best accomplished by experienced personnel in a controlled factory environment. Proper anchorage of the frame to the adjacent building construction requires careful analysis of the independent materials. Acknowledging thermal expansion/contraction, dynamic building movement, air/water/vapor retarder lines and loads imposed on the superstructure by the fenestration system are all vital to the success of the installed product. Architects/Engineers are encouraged to meet with the fenestration manufacturer to ensure that the overall design will meet the requirements of the Contract Documents.

2. **Sealants and Caulking:** Silicones or polyurethanes are the preferred materials for caulking perimeter joints. Joints should typically be 3/8" to 3/4" wide and have high-range movement capability and be UV resistant. Polyurethane sealants should be used with porous materials and for joints between porous and nonporous materials. Silicone sealants should be used with nonporous materials. Check feasibility of installing sealants ahead of time.

A sealant primer is required for contact with all porous materials. For non-porous materials, need for a sealant primer depends upon type of material or finish (e.g., clear- or color-anodized or painted). Always require field-adhesion and compatibility tests to determine whether a primer is necessary for contact with non-porous materials.

When designing joint widths, consideration should be given to applicable fabrication and erection tolerances.

Establish the compatibility of sealants and ramifications of using more than one generic type of sealant (e.g., silicone and polyurethane).

3. **Flashing and Sheet Metal:** Recommended flashing type is 1- or 2-piece dull stainless steel with drip. Neither PVC nor EPDM flashing is permitted, since the former becomes brittle over time and the latter is difficult to form, shape, etc.

Flashings should be shop-fabricated, with integral end-dams and splices, and should not be modified in the field to facilitate installation without prior approval of the Architect/Engineer.

See commentary under "Throughwall flashing with drips provided at heads and sills" for related installation recommendations.

**4. Glass and Glazing:** Types of glazing include the following, without limitation (the Architect/Engineer should be familiar with the glazing types, methods of fabrication, and inherent properties with respect to the specific end-use configuration):

- Float glass.
- Insulating glass.
- Reflective glass.
- Heat-treated glass.
- Spandrel glass.
- Laminated glass.

A life cycle cost analysis should be conducted for various types of glass for a given project to determine the best choices available with regard to cost effectiveness, energy savings, etc.

Glazing seals vary widely in their use, composition and performance. The basic components making up glazing seals include: sealants, glazing tapes and gaskets, which can be used together or independently to provide weathertight seals between the glass and frame. Glazing options are as follows:

- Wet glazing using sealants.
- Dry glazing using tapes and gaskets.
- Wet/dry glazing including a combination of sealants, tapes, and gaskets.

Glass can be factory- or field-glazed. Factory-glazing is generally more cost effective and provides more consistent quality and workmanship. However, factory-glazing can conceal nonconforming glazing work. For major projects, the Architect/Engineer should periodically review the manufacturer's assembly process during fabrication with emphasis on early work. Glazing stops should be removed randomly to check glazing components such as setting blocks, jamb blocks, insulating glass unit edge seals, and the location and size of weep holes when the units are delivered to the site to ensure that the factory-glazing was performed in accordance with the Contract Documents.

A glazing system consisting of butyl tape with silicone sealant cap bead on the outside of the glass and wedge-type or foam gaskets on the inside of the glass provide a durable and reasonably reliable glass-to-metal seal. The recessed cap bead seal provides parallel bonding surfaces for optimum sealant geometry, and the sloped design for the sealant helps shed water away from the glass. Butyl tape provides a solid backup for the sealant in the joint and a reliable buffer to cushion the glass from contact with the metal frame. The adhesive quality of the tape and cap bead also reduces the tendency for the glass to "walk" laterally; but this does not eliminate the potential need for anti-walk blocks.

Low-Emissivity (Low-E) glass has an invisible metal or metallic-oxide coating that reflects the long wave infrared portion of the heat spectrum, whose wavelength is longer than 3000 millimicrons. The long wave infrared is radiant heat produced by an electric coil-type heater, as well as sensible heat given

off by a hot air register. Re-radiated heat from room furnishings that have absorbed solar energy is another form of sensible heat.

Low-E coatings reduce winter heat loss through glass by reflecting the long wave infrared back into the occupied space. Used in conjunction with tinted (heat-absorbing) glass in an insulating unit, Low-E coatings reject re-radiated heat from the tinted glass to the exterior, which is an effective way to reduce interior summer heat gain.

Insulating glass units with Low-E coatings applied to either the second or third glass surface can achieve 0.30 U-Values. Filling the air space with Argon gas can further improve the U-Values. For example, a Low-E coating in an insulating glass unit having solar-reflective glass can have a 0.10 shading coefficient and a 0.25 U-Value.

Colored spacers are available and should be specified if applicable to design requirements or to the system used.

Size and weight of units should be reviewed to determine glazing feasibility. Protect units during delivery to prevent racking and slippage.

Spandrel Glazing is available in two forms: 1) with a ceramic coating, which is normally applied to the second (indoor) surface for monolithic glazing or on the third or fourth surface for insulated glass; or 2) with a reflective coating, which normally matches the coating selected for the vision glass both in color and on the surface.

Monolithic glazing is discouraged because of condensation potential in the winter months. (To reduce these problems if a monolithic glazing is desired for a project, use a vapor retarder on all interior edges and surfaces with all joints and holes forming the shadow box taped so moisture is effectively prevented from condensing on the back of the spandrel glass. There is also concern that volatiles in the insulation and other materials of the shadow box will form deposits on the spandrel glass, consequently damaging the coating as well as degrading the appearance.

Only one type of insulating spandrel glass is included which uses the interior lite coated with a ceramic frit. This frit should be used only on surface number 4 because sealants used to fabricate these units are not compatible with ceramic-coated surfaces. Adding colorants to glass affects appearance and reduces visible light transmittance and increases solar energy absorption by reducing solar transmittance. This leads to higher stresses with greater potential for breakage. To compensate, heat strengthening or tempering is necessary. Therefore, both panes in insulated spandrel glazing shall be heat strengthened.

**5. Finishes:** PVDF-type finishes (polyvinylidene fluoride), consisting of coating systems using either Kynar 500 or Hylar 5000 resins, are more versatile for architectural finishes than anodizing. PVDF is more resistant to building wash, lime leaching, acids, etc. Warranties on PVDF finishes are typical (5-year manufacturer and 10-year applicator warranties) depending upon who is providing the warranty. This must be specified. PVDF finishes are not recommended for use at entrances without abrasion-resistant topcoats, because they are softer finishes than anodized or epoxy/urethane finishes and are less resistant to abrasion from hand contact. Specifying a precise color as early as possible (e.g., referencing a manufacturer's paint chip number) is helpful in reducing lead times and ensuring competitive bids.

Anodized finishes have excellent solvent-, abrasion-, and UV-resistance. It is recommended that Architects/Engineers meet with fenestration manufacturers, well in advance, to discuss fenestration performance, glass, and hardware, in order to select a product appropriate for the application.

No mill finished aluminum is to be allowed in exposed exterior applications, because of oxidation of aluminum and the likelihood of resulting staining.

See "Hardware" under "Materials" for finish recommendations.

**6. Hardware:** Window hardware should be fabricated using aluminum, stainless steel or other noncorrosive metals compatible with aluminum. Latching hardware and strikes should generally be made of stainless steel to avoid short-term replacement. The following comments apply to doors.

Aluminum is the preferred material for entrance doors and frames because of the many finishing options for the Aluminum which allows the matching of other materials where continuity is desired. Aluminum is also well suited to the climate in the region of the Upper Great Lakes.

Basic considerations when detailing and specifying entrance door hardware include security, life safety, durability, maintenance, and compatibility with and integration into the entrance system. Not unlike the hardware selection process for wood or hollow metal doors, hardware items fall into the following categories:

Operating hardware: hinges, pivots, closers, balanced door mechanisms, revolving doors, and automatic operators for swing, slide, and revolving applications.

Securing hardware: locks, latches, security devices (e.g., card readers, combination locks, magnetic locks, monitor switches), exit devices, flushbolts, and cylinders.

Accessory hardware: stops, holders, push/pulls, thresholds, and protective plates.

The Architect/Engineer can contact aluminum door manufacturers, hardware manufacturers and hardware consultants for assistance in specifying and detailing aluminum door hardware. Entrance door hardware should be coordinated with hardware used in other parts of the project. Entrance door hardware normally is specified in the technical section for storefront. The project specifications should include a detailed list of hardware for aluminum doors; and the hardware supplier, in turn, should prepare a detailed hardware schedule that closely corresponds to the detailed list of hardware. The hardware schedule should be coordinated with the shop drawings.

Since factory automated equipment produces a stronger and better finished aluminum door and frame, preparation for hardware must be performed at the door factory. The hardware supplier should furnish dimensionally accurate templates to the door manufacturer in a timely manner.

Butt hinges support the door in its frame and provide single-acting swing action. Pivots, either center- or offset-hung, are preferred over hinges to swing large and/or heavy doors. Double-acting doors must always utilize center-hung pivots.

All types of closers may be used on hinged or pivoted entrance doors; however, concealed overhead closers do not perform well at low temperatures and require more maintenance. Floor closers are

suitable for high traffic doors and heavy and/or large doors. Their sealed installation in the slab renders them vandal-proof and weatherproof. The use of special hydraulic oil (cold weather fluid) maintains its viscosity at low temperatures. Coordination with related hardware, including pivots and overhead stops, is facilitated. Regarding ADA-AG compliance, at 90 degrees opening, floor closers' closing force is 100 percent more efficient than that of surface closers. When using floor closers, closely coordinate the placement of the related cement case with the concrete trade. Bottom pivots and floor closers should only be considered for use when they can be kept relatively free of de-icing salts, dirt, and other deleterious matter.

**Balanced door hardware:** A swing door that rotates around a rolling pivot providing a balance of wind pressure on the door leaf. This facilitates operation under high wind or stack pressure conditions and provides the widest possible opening with the smallest swing arc.

**Automatic operators:** Various types available for ADA-AG compliance include electro-hydraulic, electro-pneumatic, and electro-mechanical (all-electric). Factors to consider when selecting an automatic operator include: door size and weight, wind conditions (pressure), stack action, frequency of use, location of power unit, and electrical requirements.

**Hardware metals and finishes:** Corrosion-resistant, non-ferrous base metals and finishes. Dull stainless steel (US 32D-BHMA 630), dull chrome-plated brass (US 26D-BHMA 626), dark bronze, oil-rubbed (US 10B-BHMA 613), and satin bronze-clear coated (US10-BHMA 612) are the most common finishes for entrance door hardware.

For more detailed information on entrance door hardware, see manufacturers' literature, DHI literature, AAMA Aluminum Store Front and Entrance Manual, Section 3 and NAAMM Metal Finishes Manual.

## **C. INSTALLATION**

Too often, many fenestration problems encountered in the field can be traced back to improper installation. The shop drawings/installation instructions furnished by the manufacturer for large or complex projects should provide complete detail, including all the accessories needed for anchorage/fastening of the elements into the exterior wall. It is vitally important that samples of the products to be installed are provided to insure understanding and compliance with the Contract plans and specifications, approved shop drawings and the manufacturer's written installation requirements. This should be accomplished by means of viewing and ultimately approving proposed/expected means, methods and end results as appropriate, before installation work begins in earnest.

### **1. Installation Practices to be Provided When Applicable**

**a. Roles of fenestration manufacturer and approved installer defined:** Poor installation practices can undo the effects of well-prepared Contract Documents and quality control measures undertaken by the manufacturer in the factory. Close collaboration between the manufacturer and installer is essential to a successful project, each understanding its respective role in the process.

**Manufacturer's role:** Provide literature describing the best methods of installing and anchoring standard products. For custom applications, the manufacturer should be capable of interpreting the Contract Documents and preparing shop drawings showing applicable installation methods. If requested, the manufacturer should be able to recommend approved installers. The

manufacturer should be capable of fabricating elements in accordance with the Contract Documents and the approved shop drawings using skilled mechanics, proper methods and equipment. Following fabrication and finishing, components should be properly marked to indicate their location on the building, packed to prevent damage in transit, and delivered to the job site. A technical representative of the manufacturer, if available, can provide the installer with information and guidance during construction.

**Manufacturer-approved installer:** A firm having a successful record within the immediate past five years of installations, similar in nature and scope to the one being bid. This record should be verified by appropriate references. The installer should demonstrate his/her possession of necessary tools and equipment or sufficient financial resources to acquire them, and the ability to meet payroll and other project costs. The installer should indicate what work will be executed by his/her own forces and/or by other specialized trades.

Good field supervision, attention to detail, and establishing responsibility for the respective trades, such as caulking, hardware, glazing, etc., are essential for achieving a successful fenestration installation.

**b. Submittals and Mockups:** Prospective manufacturers should be required to submit a set of proposal drawings with bids and/or for approval for custom design/high profile projects, including but not limited to, historical preservation projects.

Manufacturers of fenestration components, glazing, and sealant should review architectural drawings, as well as each other's related submittals, as a normal part of their work, for applications that incorporate their respective materials.

Prior to preparing and submitting bids on renovation projects, it is recommended that prospective manufacturers and installers be present during the removal of existing fenestration units to observe original and remaining construction details and installation of samples. It is also recommended that each successful bidder, or acceptable manufacturer listed in specifications, be required to furnish a sample unit for the proposed system. Recommended award of Contract can be based on review of same by the Architect/Engineer, in retrofit or test mockups. Field testing the installed application is also recommended.

Subcontractors should list their proposed material suppliers on the General Prime Contractor's Sub list Form, indicating areas of the project where these suppliers will specifically be involved.

Shop drawings should be prepared by the manufacturer--since he/she is most knowledgeable about the products and can facilitate coordination with the installer.

Custom applications require a laboratory mockup which can expose flaws to the manufacturer and installer. A modified standard design needs no mockup, because the fenestration section basically remains unchanged. Meeting with all concerned parties at completion of final shop drawings is suggested.

**c. Curtainwall Insulation:** Mechanically attach curtain wall insulation to curtainwall frame. Curtainwall insulation shall have a foil-faced vapor retarder. All seams and edges shall be taped with a foil tape that has a solvent based adhesive.

**d. Pre-installation meeting:** Whether fenestration is field- or factory-glazed is determined by various issues that should be addressed in pre-planning meetings and ultimately included in the specifications on a project-specific basis.

**e. Field testing:** The project specifications should require field testing, paid for by the Owner, in accordance with AAMA field test methods and performance recommendations, to ensure field quality control. Field tests identify leaking joints immediately after installation begins. AAMA 501.2 is for wall units, AAMA 502 is for windows and sliding glass doors, and AAMA 503 is for storefronts, curtainwalls and sloped glazing systems. AAMA 502 and AAMA 503 specify field test procedures for measuring air infiltration and water penetration. AAMA 501.3 describes the method for determining the resistance of installed exterior windows, curtainwalls, and doors to water penetration, when water is applied to the exterior face, simultaneously, with a static air pressure on the interior face lower than the static air pressure on the exterior face. AAMA 502 provides Methods A and B. Both utilize a portable test chamber to simulate wind pressure (positive or negative). The methods differ as to whether or not the perimeter seals, subframe/receptor system, and frame corners are tested under pressure. A manufacturer's representative should always be present during a field test, and testing laboratories utilized should be AAMA-certified.

**f. Maintenance manual:** The fenestration manufacturer and installer should meet with the Owner's Project Representative to review cleaning, maintenance and reglazing procedures.

Maintenance instructions, hardware adjustment, weather-stripping replacement, parts replacement, glass replacement and warranty information (including identification of project for warranty) must be furnished by the fenestration manufacturer through the General Prime Contractor to the Owner's Project Representative, in the form of a maintenance manual.

## **2. Installation Practices to be Avoided**

**a. Puncturing of flashing:** Care and coordination must be provided to ensure secure perimeter fastening of the fenestration system, without damaging the integrity of the flashing above steel lintels. It is recommended that the placement and shape of the formed flashing be reviewed with the fenestration manufacturer to prevent penetration.

**b. Anchorage by other than fenestration installer:** It is recommended that the fenestration installer assumes full responsibility for installing anchor connections to the building structure. Other trade subcontractors who may perform this work may not completely understand the connection's purpose or the need to precisely position the anchors due to lack of familiarity with the fenestration system.

**c. Use of fiberglass insulation as air barrier or vapor retarder:** Water vapor is carried from one place to another in a current of air or by diffusion. Of these two mechanisms, vastly more moisture may be moved in air currents allowed by the air leakage. Conventional fiberglass is neither an air barrier nor a vapor retarder, but rather the same material sometimes used in air filters. An effective air/moisture barrier of a totally different material or a membrane covering the insulation is necessary.

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